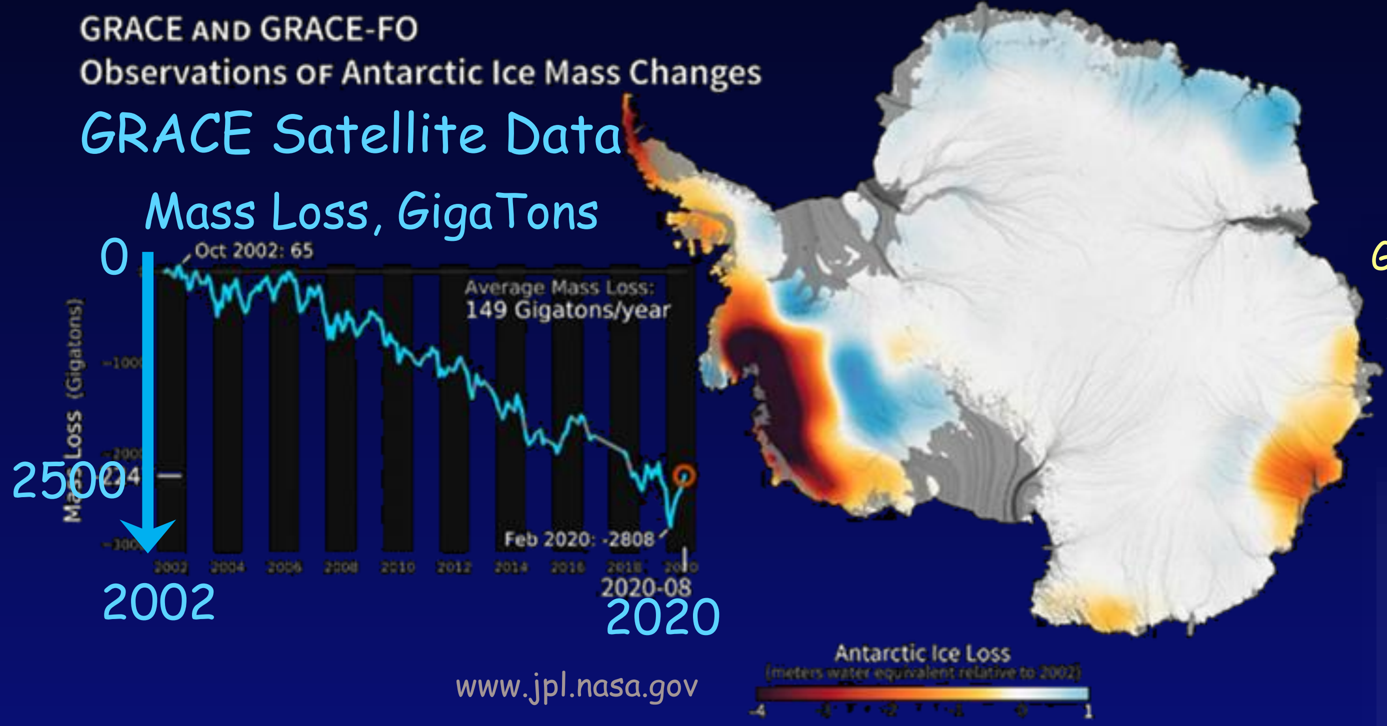
# Antarctica ice sheet basal melting enhanced by high mantle heat

(a geophysical perspective)

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# Antarctica is losing ice mass by basal melting –

a principal mechanism proposed by glaciologists

In contrast, Greenland looses ice mass at the surface through atmospheric effects

## Glaciological concept for Antarctica:

The main loss of ice mass in Antarctica is through ice sliding, not by the ice surface melting.

- Deep geodynamic processes cause melting of ice-sheets at the ice-rock interface.
- Thawing of subglacial sediments lubricates the ice-rock interface even at low melting rates.
- This promotes ice sliding to the ocean.
- And leads to a dramatic reduction of ice mass.

These deep thermal anomalies, triggering the ice-sheet sliding, are reflected in heat flux

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## Analogues in nature:

The Heinrich events in North Atlantics:

- episodic massive break-offs of large ice masses - every few thousand years.
- Cause: basal ice-sheet warming;
- Formation of a "slippery lubricant" layer at the base of the ice-sheet
- The extremely fast onset - on time-scale of years – of ice break-off

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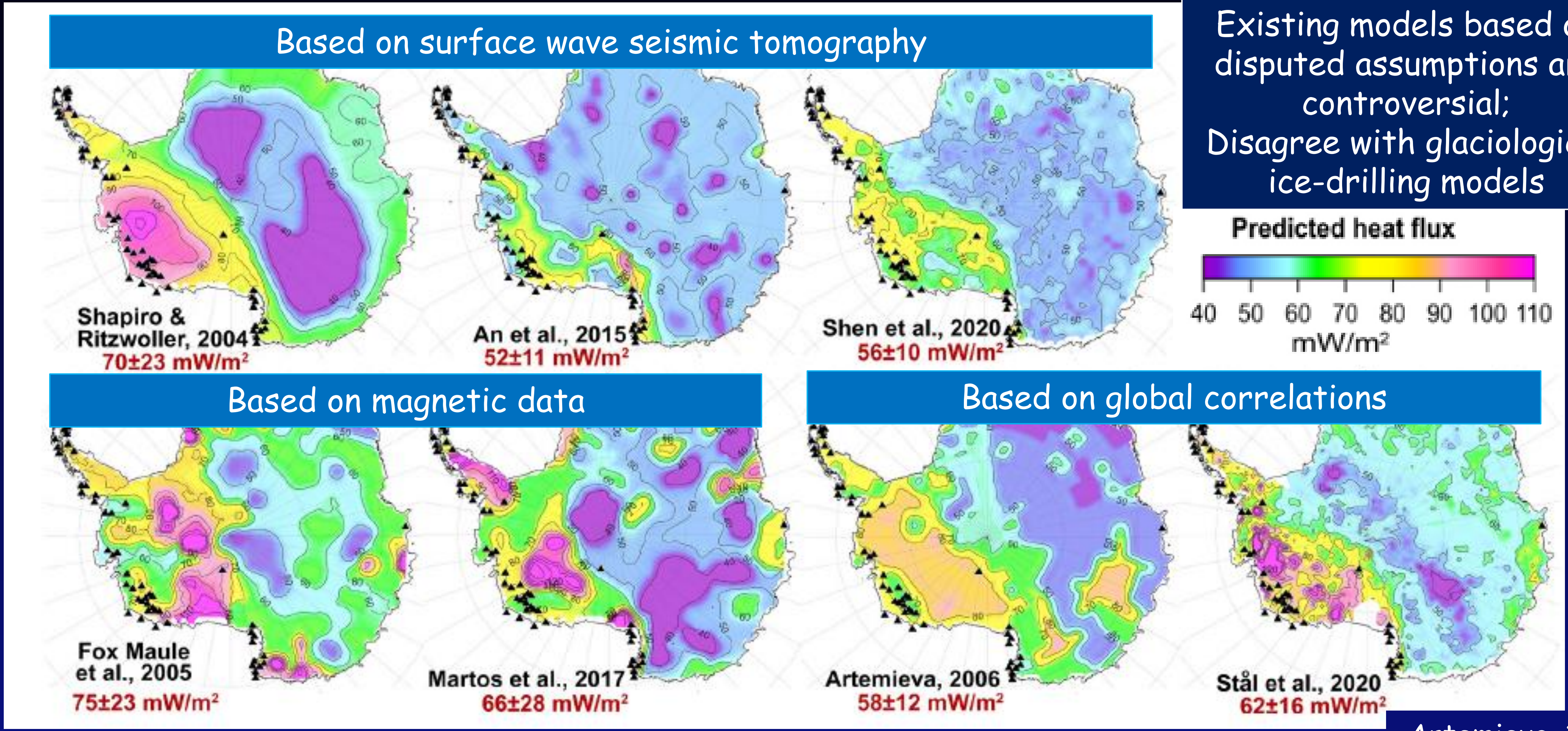
# Geophysical models for Antarctica heat flux

Existing models based on disputed assumptions are controversial;
Disagree with glaciological ice-drilling models




Artemieva, 2022

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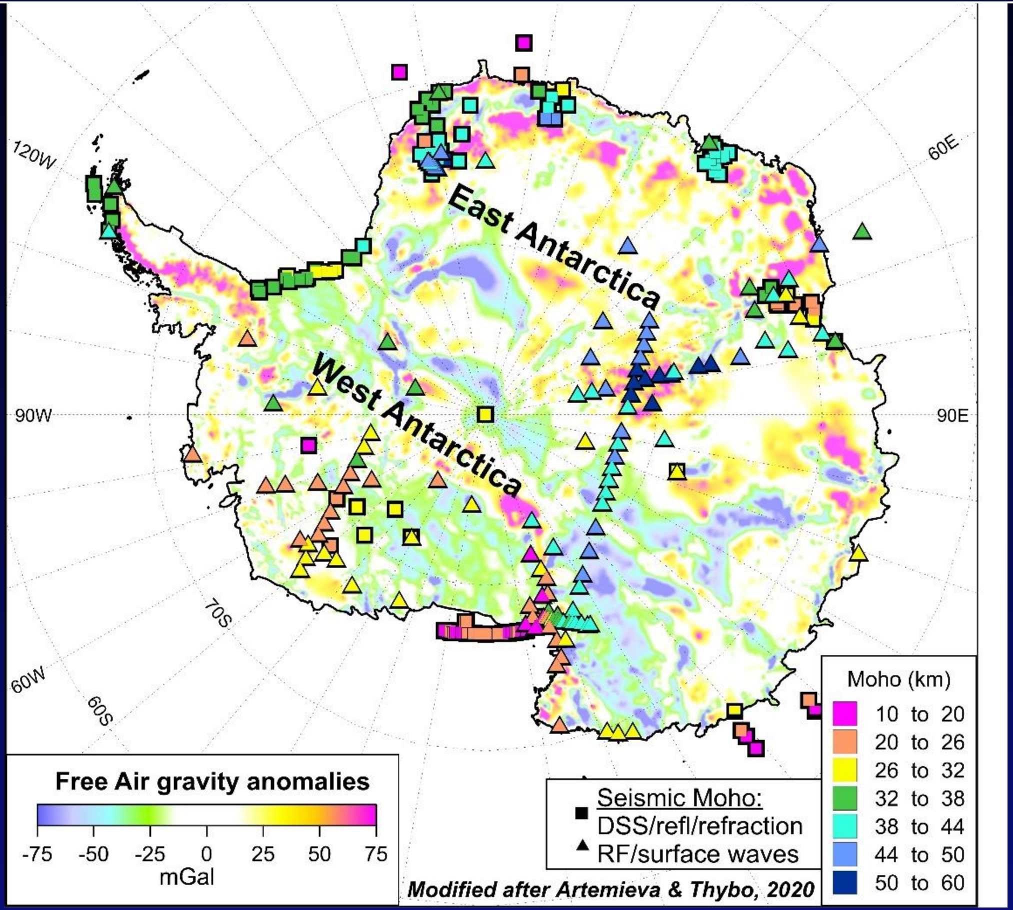
# Thermal isostasy method

For method description see:
Artemieva, 2019, 2 papers in ESR
Artemieva & Shulgin, 2019, Tectonics

Moho depth (symbols) and FA anomalies




Artemieva & Thybo, 2020

## Assumptions and step-by-step procedure:

1. Regional isostasy – supported by ~0 mGal FA;
2. Deviations from crustal isostasy → anomalous topography AT (requires data on Moho depth);
3. AT anomalies are due to T variations in lith. mantle;
4. → T anomalies (vertically averaged from Moho to LAB) with respect to a location with AT=0
5. T anomalies → thermal LAB
6. T anomalies → heat flow (based on Pollack & Chapman geotherms parameterized by heat flow)

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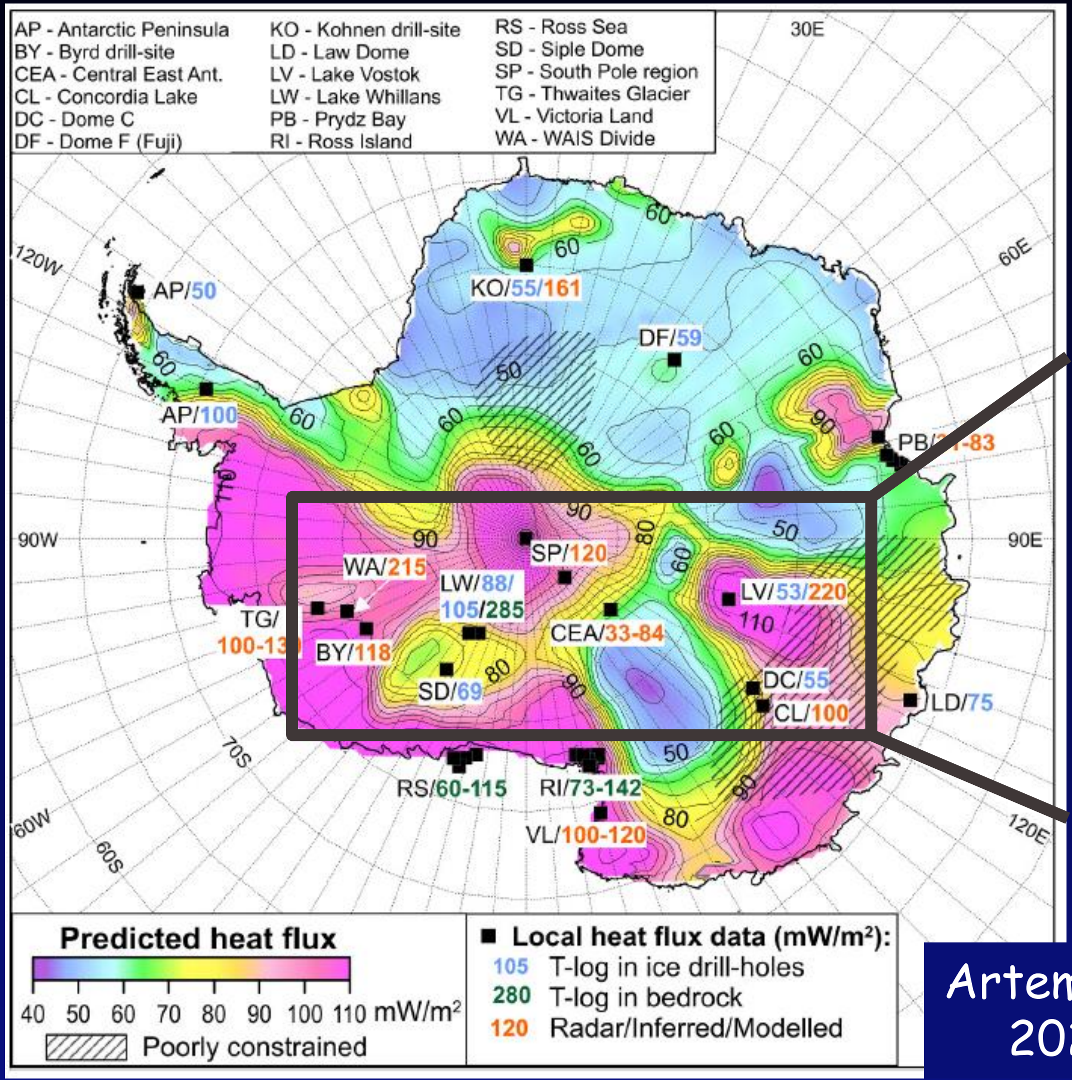
# Results: Predicted heat flux vs local models

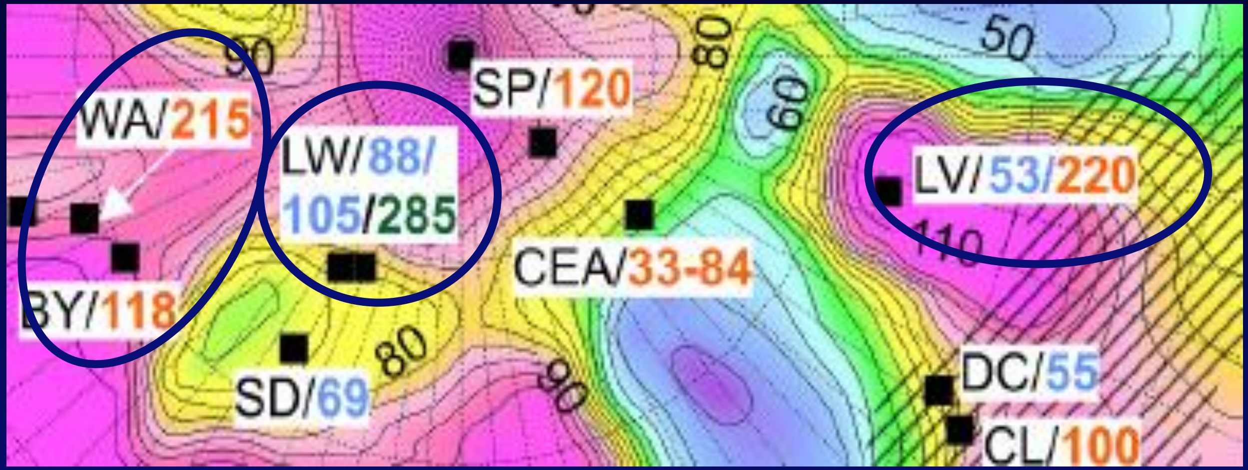



Artemieva, 2022

Background colors – new model.

Numbers – HF values from local ice-drill studies.

- Huge discrepancies between glaciological models;
- Only local models, no continent-scale model




■ Local heat flux data (mW/m²):

105 T-log in ice drill-holes

280 T-log in bedrock

120 Radar/Inferred/Modelled

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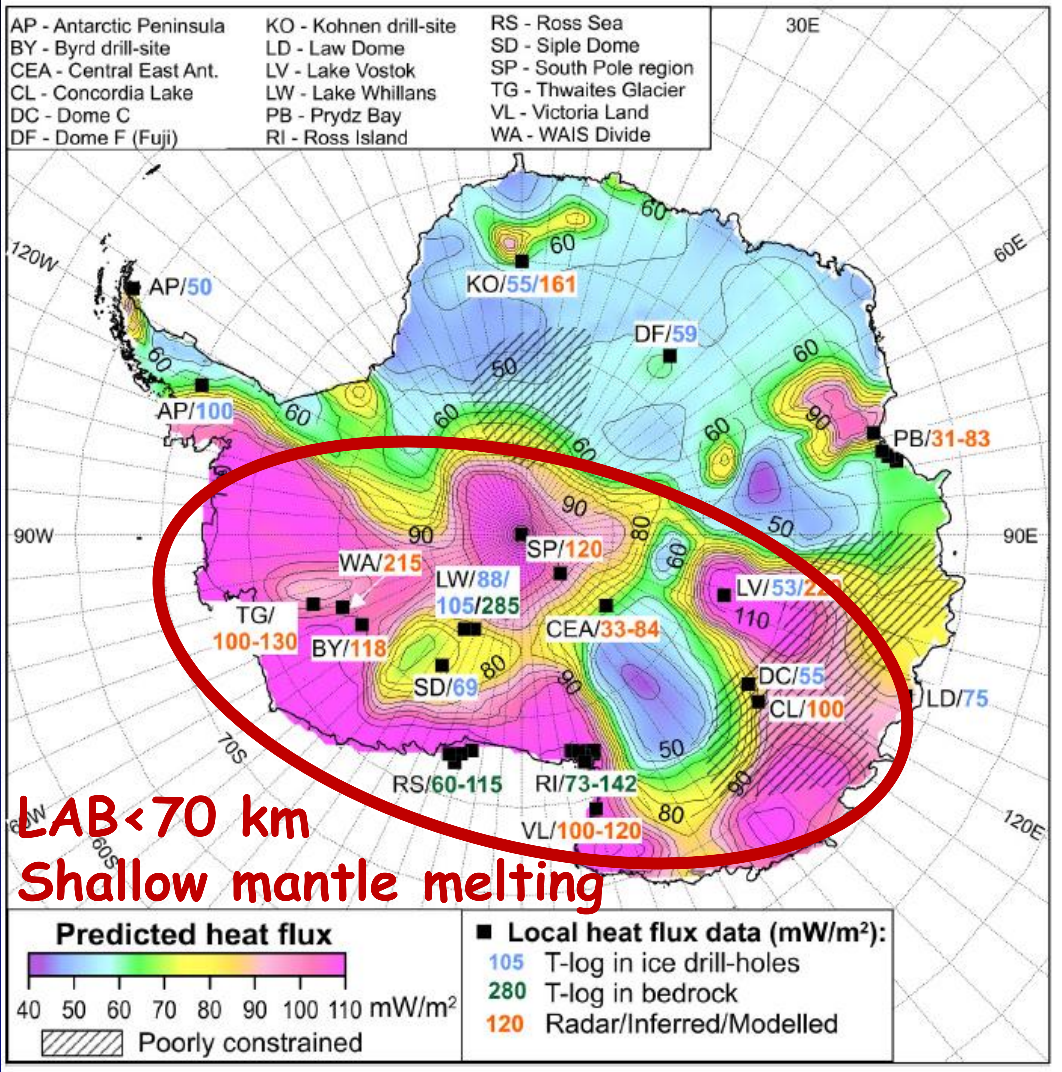
# Results & Conclusions: Predicted heat flux




The rate of Antarctica ice basal melting is significantly underestimated.

Compared to previous results:

(i) the area with high heat flux is double in size;

(ii) the high heat flux anomalies are 20–30% higher.

Extremely high heat flux (>100 mW/m2) in most of West Antarctica, the South Pole & the Lake Vostok regions requires:

- an ultra-thin (<70 km) lithosphere;
- shallow mantle melting.

This may promote:

- thawing of the basal ice,
- lubrication at the ice-rock interface,
- the ice-sheet sliding to the ocean.

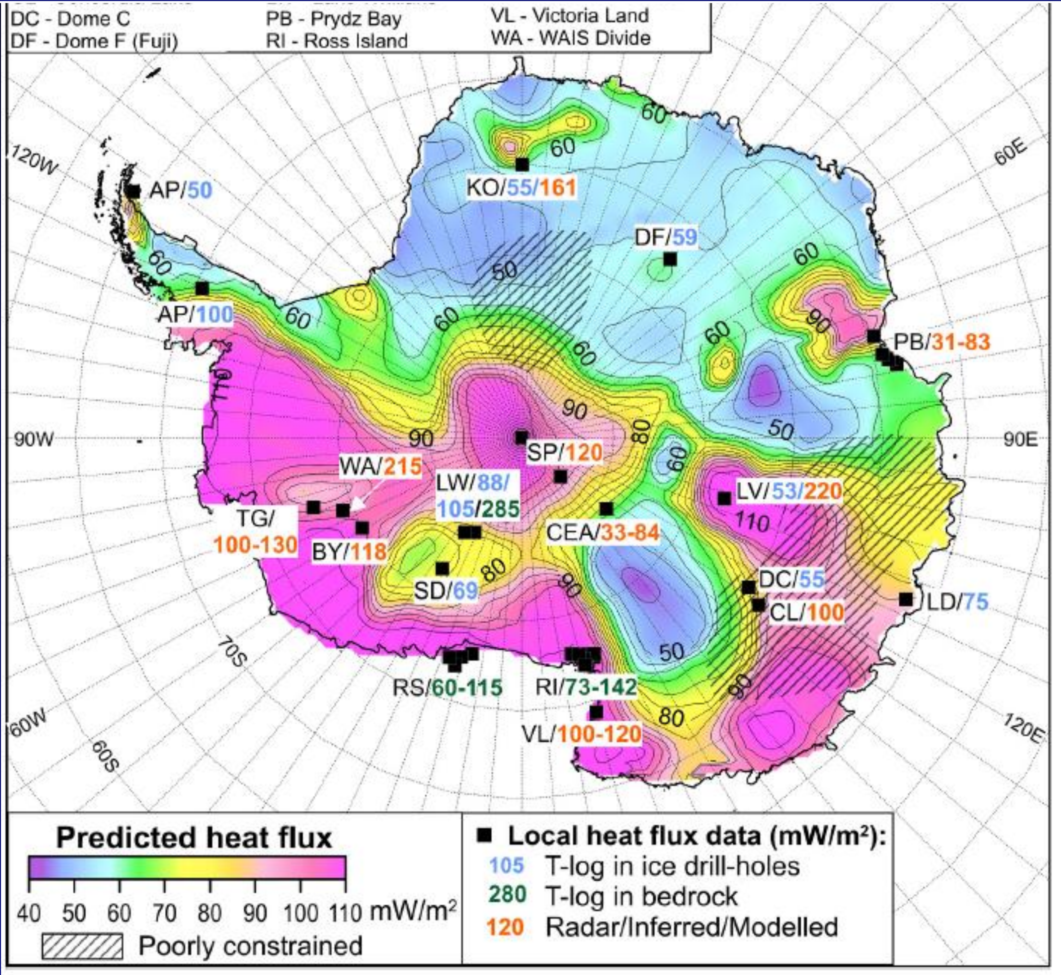
This may lead to dramatic reduction of ice mass, such as in the Heinrich events.

Artemieva I.M., *Earth Science Reviews*, 2022, https://doi.org/10.1016/j.earscirev.2022.103954

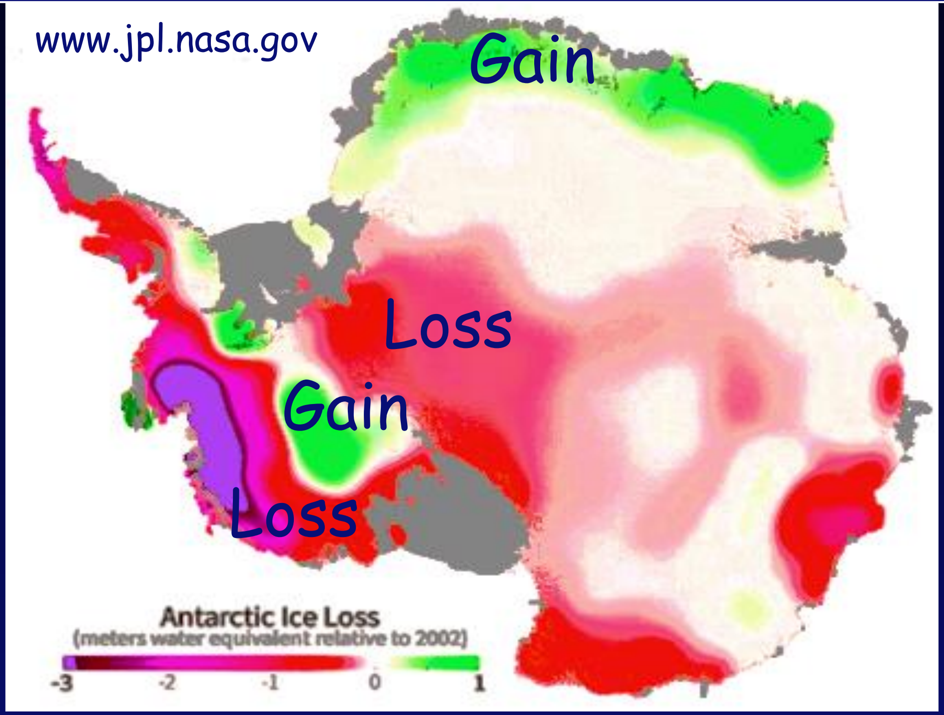
# Results: Predicted heat flux (left)

These maps should agree only in big terms because they show different things

## Regions where ice melts from below




## Ice loss by sliding (GRACE data)




The ice-sheet loss is by lubricated sliding, → regions of high heat flow (= high melting rate) may be far away from near-coastal regions where the ice slides to the ocean

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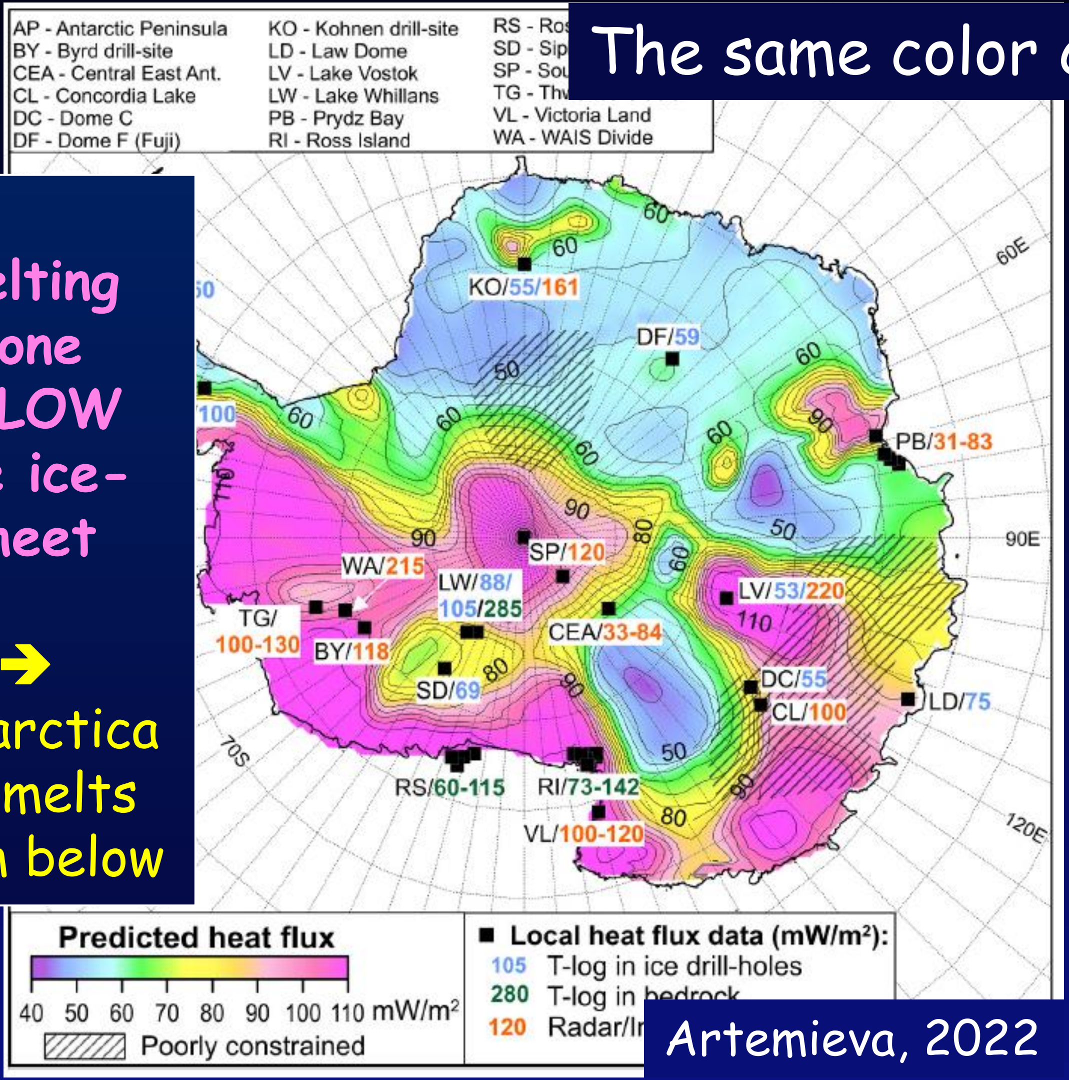
# .... and Greenland by the same method

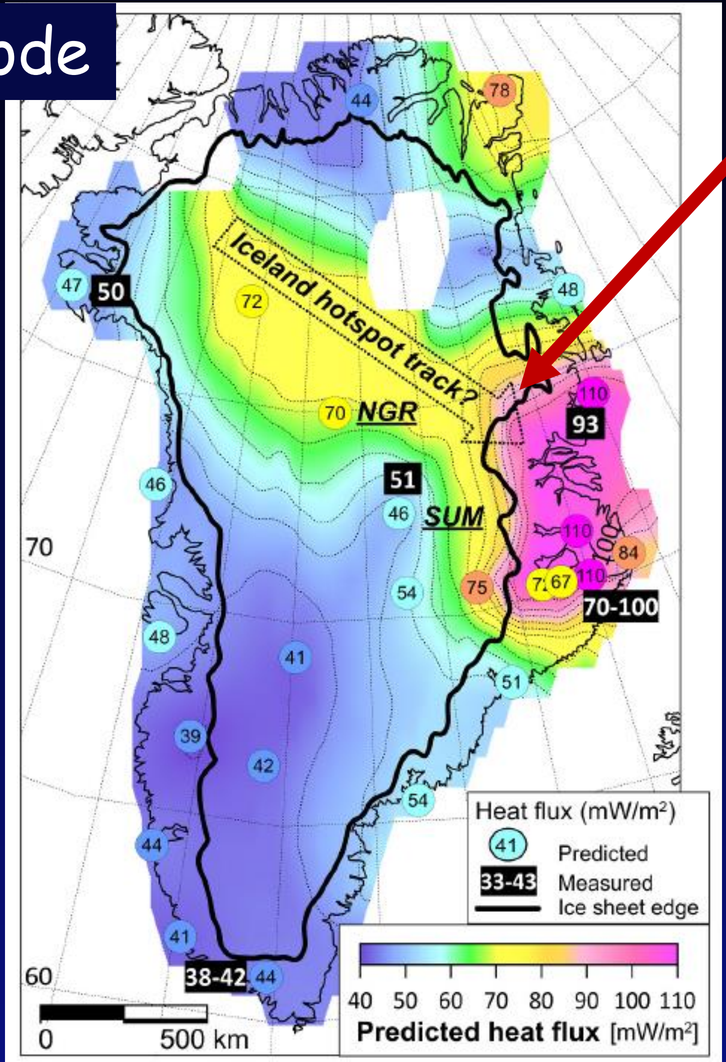
The same color code




Artemieva, 2022

Melting zone BELOW the ice-sheet

➔ Antarctica ice melts from below




Black line = ice-sheet margin

Yellow = Iceland hotspot track ?

Melting zone OUTSIDE the ice-sheet

➔ Greenland ice melts from the top

Artemieva, 2019

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